PUBLICATION 665
CIRCULAR 148

ISSUED JANUARY, 1940
FIRST PRINTING

DOMINION OF CANADA—DEPARTMENT OF AGRICULTURE

SOME USES OF PLANT HORMONES

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EXPERIMENTAL FARMS SERVICE

blished by authority of the Hon. JAMES G. GARDINER, Minister of Agriculture,
Ottawa, Canada

4-12-39

SOME USES OF PLANT HORMONES

During the past three years there has been a flood of literature published on the subject of plant hormones. Much of this is of a scientific nature reporting the results of experimental work, while some is purely advertising for certain commercial preparations. Both are confusing to the mind of the average horticulturist and it is in an endeavour to present in a simple manner what is known on this subject that this circular is prepared.

The authors feel that sufficient experimental work has not yet been done to enable them to evaluate accurately the discoveries in this field, nor to outline their limitations. They seek only to clarify what is known for the benefit of the grower who wishes to do a little experimenting on his own account.

Natural Functions of Plant Hormones

Most persons are well acquainted with the established custom of rooting plants from "slips," or greenwood cuttings. Vigorous terminal shoots that are in such a condition of growth that they will "snap" like a green bean, are cut off just below a leaf joint and planted in sand. After a few days a callus forms over the cut end and eventually roots are produced from the bottom leaf joint and occasionally from farther up the stem. Then the top commences to grow and if the cutting has been grown in a window, the new growth will bend toward the light. If the young plant receives no direct sunshine, growth will be spindly without side shoots. When the terminal growth is pinched out, side shoots commence to form.

These phases of plant growth are natural phenomena which have been recognized and accepted for centuries, but it is only within the last ten or fifteen years that scientists have been finding out why these things occur, and there are still many points which are not yet clearly understood.

It was in trying to discover what made plant stems grow upwards and turn towards the light and what made roots grow down towards water that scientists discovered a group of substances in growing parts of the plant called auxins. These are to plants what gland-secreted hormones are to animals. That is, they are substances built up in one part of the plant—the growing tip—and carried to other parts to fulfil various functions.

Growth in plants is brought about by the division of individual cells of the growing parts and by the expansion of these new cells into mature ones. The presence of auxins stimulates the rate of cell division and expansion and consequently speeds up growth. So far as is known at present their function is in no sense nutritional, yet their presence is the stimulus of all normal plant growth, and the plant reacts to their presence in such a way as to bring about the natural phenomena mentioned above.

As the natural auxins are apparently governed by gravity they flow downwards from the growing tip where they are formed. If the flow is evenly distributed around the stem, normal growth takes place, but should something interfere with the even distribution, growth becomes lopsided. These auxins are rather complex organic acids which are broken down by light, oxidation, and electric radiation. Plants growing in shade grow taller and more spindly than those in bright sunshine because the auxins in the latter are destroyed more rapidly by the light. Where light strikes only one side of a plant, the auxins on that side are destroyed more rapidly, and elongation of growth is retarded. The shaded side grows more rapidly and the plant consequently bends towards the light.

The presence of auxins in the main growing point retards the development of side shoots from lateral buds. So long as the terminal growth is present, the side shoots are not produced, or remain small. As soon as this source of auxin production is removed, the side shoots develop, forming two or more leaders. That is why pinching out the central bud makes plants bushy. It is the foundation of all pruning practices.

Auxins are carried downward in the bark layer or phloem of the stem. If this path is impeded by a wound, the building up of their concentration causes stimulation of the tissue resulting in the callus that forms over the wound. When cuttings are taken, the increased auxin concentration causes the cells of the phloem and ray tissue to form into root primordia—really embryo roots—which push their way through the surface of the stem to form roots.

This is all interesting of course, but only of value if the knowledge can be applied to increase or facilitate production.

Synthetic and Artificial Hormones

A few years ago some chemists found that certain organic acids could be built up synthetically and that these had the same effect as natural auxins. This discovery has lead to the use of these chemicals in the rooting of plant cuttings.

While it is definitely known that one of the auxins, namely heteroauxin, is the chemical indolylacetic acid, it was found that several other chemicals were similar to it in behaviour when applied to plants. While a number of chemicals have a measure of physiological activity, practical developments have centred around the indolyl and naphthyl series of compounds. In practice, it has been found that the three chemicals, indolylacetic and butyric, and naphthylacetic, can be used to the best advantage. Trials indicate that naphthylbutyric and hexoic acids are also exceedingly effective agents in promoting the rooting of cuttings.

Practical Uses

The principal uses of such chemicals in horticulture are as follows:—

1. The stimulation of roots from cuttings.
2. The stimulation of germination and development of young plants from seed.
3. The stimulation of callus formation in grafting.
4. The stimulation of callus formation in the healing of wounds made in pruning.
5. The stimulation of self-sterile flowers to set fruit. This is only valuable to plant breeders.

Propagation from Cuttings

The first important field of effort was in the rooting of cuttings. To date, experimental results indicate that these growth substances, which, incidentally, are on the market under various trade names, are of considerable value, particularly in the rooting of greenwood cuttings.

Greenwood cuttings of shrubs, deciduous trees and conifers are taken at various times, from early June to early August, according to species. Most plants root best when the wood is taken just before it ceases active growth and puts out terminal buds, though some species such as *Viburnum Lantana* seem to root better from softer wood.

Terminal growths from two to six inches long are taken either by cutting off below a leaf joint or pulling the young shoot from the parent twig, which leaves a heel of last year's growth. Only the lower leaves are removed about half way up the cutting. Too much transpiration from foliage will cause the

cutting to dry out and die, but the more foliage the cutting can support, the more food will be given back to the cutting. The greatest problem in propagation from greenwood cuttings is to retain the foliage in fresh condition. This can only be done by keeping the air temperature as low as possible, and the humidity high. This problem becomes more acute where a long period is needed, in order to produce roots, and this seems to be the greatest advantage in using the "Hormones" as they induce more rapid action in most plants.

Most plant species which root from cuttings normally either with ease or moderate difficulty may be propagated in this way with greater ease and speed when the cuttings are treated with "growth substances." The increased speed cuts down the problem of transpiration which probably explains the increased percentage in sorts normally difficult, as the number of untreated cuttings which eventually root does not seem to vary with the treated cuttings in plants such as cedar, in which the transpiration problem is not so important, though the treated cuttings root in about half the time.

Most publicity has been given to the treatment of cuttings with solutions of these substances. Because there are so many variable factors, this method is discussed here at considerable length. This does not mean that it is recommended in preference to the much more simple dust method. In fact, it would appear that the dust method will, in time, be used exclusively, due to the greater likelihood of error in treating with solutions.

FIG. I.—Left, solution method; right, dust method of treatment.

Solution Method

The actual treatment consists of standing the cuttings to a depth of $\frac{3}{4}''$ to $1''$ for a stated period of time in a solution containing a definite amount of the active chemical. As many factors enter into the solution method of treatment, care must be taken to follow directions closely. The success of the treatment depends upon the absorption of the correct amount of the chemical into the cutting. As the effective range is quite limited, the amount of chemical

absorbed must be fairly uniform in each treatment of cuttings of the same species or variety. This absorption is influenced by:—

1. The rate of transpiration, which is equivalent to the rate of evaporation of moisture from the leaves.
2. The time period of the treatment.
3. The strength of the solution.

Environmental Factors

The rate of evaporation from the foliage will be more rapid at high temperatures than low. Where the air is dry, evaporation will be more rapid than where humidity is high. Cuttings exposed to bright light will absorb more solution than those in light which is less intense. Direct sunlight is almost sure to prove fatal. In cuttings which have large leaves, transpiration will be more rapid than in small-leaved sorts. Where leaves are crowded together, evaporation will not be so rapid as where cuttings are left more spread out during treatment.

During the treatment of some cuttings at the Central Experimental Farm, measurements were taken of the amount of solution absorbed per cutting, and were found to vary from ·5 c.c. to 5·3 c.c. in twenty-four hours under varying conditions, as discussed above (one teaspoon is equal to about 5 c.c.). That means that where a standard solution is used for a definite period, the treatment may actually vary widely in terms of the chemical absorbed, due to conditions not taken into account by the average practical horticulturist.

All cuttings should, therefore, be treated under conditions which are as uniform as possible. Full north light in a room at ordinary temperatures 65 to 70° F. with humidity around 50 per cent, with the cuttings loosely bunched together, will give the best results.

Time

The time period of the treatment naturally has considerable effect on the absorption of the solution. As evaporation from the leaf surface takes place continuously, particularly during the hours of daylight, material is being absorbed all the time the cutting is standing in the solution. A weaker solution therefore is needed where a long treatment is to be given than when the cutting is to be treated just for a few hours.

Some plants seem to respond to standing in a weak solution for a long period of time, better than treating them for a few hours in a stronger solution, but for general use, an 18 to 24-hour period of treatment seems to work in best with daily routine of work, and has been the usual period used in tests at the Central Experimental Farm.

Solution

Where other factors remain fairly constant, strength of solution is the factor which varies with the species or variety. This is influenced by the type of wood of the cutting, and by its natural ability to root from cuttings. As a general rule, herbaceous plants require weaker solutions than woody ones, and plants with soft wood lower concentrations than those with hard wood. Optimum strength of solution may vary with the season, due to condition of the wood. Cedars (Thuja) and Yews (Taxus) for this reason require from 10 to 20 parts per million less in summer than in the fall.

The strength also varies with the ability to root. Plants which normally root easily respond to rather weak solutions, whereas more difficult examples need higher concentrations. Weigelia roots well at 40 ppm., whereas lilac, which is normally difficult, roots best at 80 ppm.

The latter, however, does not always hold good. Apples which have nowhere rooted in sufficient quantities to prove practical, from a commercial standpoint.

have given what little response they have made with a treatment of 40 ppm. Concentration therefore is something that must be determined for each species and variety, but after some experience the propagator can judge pretty well what concentration to use.

FIG. II.—Top, too strong, note large number of roots and burning of base. Centre still too strong; bottom, optimum treatment with normal rooting.

Even in the effective range of treatment, there is a great difference in the type and extent of rooting produced. Treatments on the weak side usually stimulate root production from the basal node only, as is the case in untreated cuttings. The optimum strength causes stimulation of vigorous roots from the basal and second nodes, with occasional roots from the internodes. Treatments on the strong side cause burning of the basal end with excessive swelling of the internode. Frequently the bark is split as quantities of fine, hairlike roots grow out in great profusion. Many of these fine roots die later when the cutting is transplanted, and the mortality rate in transplanting is higher than in the case of cuttings receiving the optimum treatment. (*See* Fig. II.)

In speaking here of concentration, the authors refer to the strength of solution used in the treatment. Any figures given represent the number of parts of chemical per million parts of water. Several chemicals have been used for odd tests, but those most commonly used in solution at the Central Experimental Farm have been indolylacetic, indolylbutyric acid, and naphthylacetic acid, while indolylacetic acid has been the active reagent in dust treatments.

These are the active reagents in all the commercial preparations, which will be discussed later, and while their reactions are very similar, each has a few characteristics of its own.

Indolylacetic acid is the safest of the three to use. Though perhaps not so potent as the other two, it has a much wider range of effectiveness when used in solution. In some cases, any solution of it containing from 25 to 100 ppm. has been successful in producing roots where the range with the other two would be from 50 to 80 ppm., though this would produce more roots than any of the indolylacetic treatments.

Indolylbutyric acid is the commonest one of the three in commercial preparations, but in tests at the Central Experimental Farm, it does not produce quite such sturdy roots as naphthylacetic acid, though apparently it is active at the same concentrations. It has also another drawback as weak solutions of it in water lose their usefulness after about seventy-two hours, whereas solutions of naphthylacetic apparently remain unchanged for a much longer period.

All of these acids will kill the tissues if the concentration is too high, and in many cases actual damage has been caused as well by using a treatment that is too low. As an example, in one variety of lilac, the control cuttings, and also those treated at 10 ppm. indolylbutyric acid, remained healthy, those treated at 20 ppm. were damaged, the effective range was 40 to 100 ppm. with the optimum at 80 ppm., while death occurred again at 160 ppm. (*See* Fig. III.)

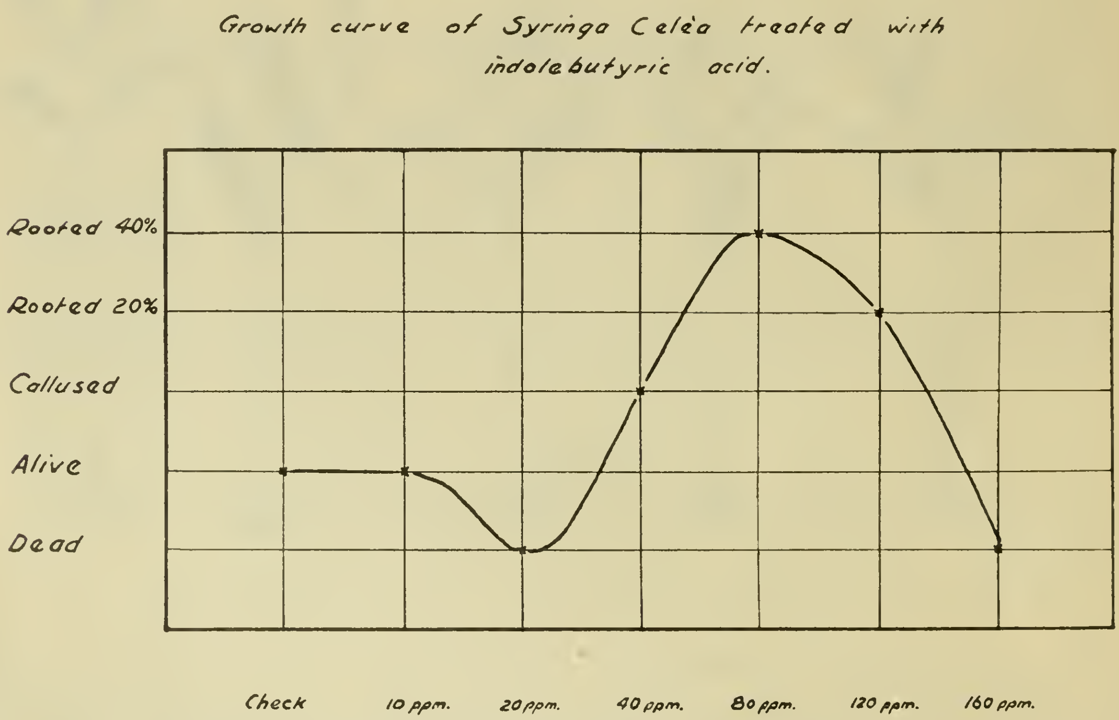

FIG. III.—Growth curve of Syringa Celia treated with graded concentrations of indolylbutyric acid. (*See* cut, Scientific Agriculture, 18:7, p. 385.)

Hardwood Cuttings

Though many claims have been made concerning the effective stimulation of rooting of hardwood or dormant cuttings, experience at the Central Experimental Farm has been without positive results.

In the winter of 1937-38, duplicate lots of cuttings were taken, composed of some twenty species and varieties. One lot was treated by standing the base in solutions of indolylbutyric acid at recommended strengths for twenty-four hours. Both lots were then stored in sand in the usual manner, until planted in the field in spring.

No stimulation of rooting could be noticed. Two species of Philadelphus gave higher percentage of rooted cuttings from the treated lot; on the other hand, several species from the untreated lot were more successful than the same species treated with hormones. It would appear that these substances are not active at temperatures below that required for ordinary growth.

Treatments for Various Species of Greenwood Cuttings

The following list of species, together with successful treatments, may prove of assistance to propagators. It must be remembered, however, that this table is based on the results of only two seasons' work, in some cases only one series of tests in each species. For this reason, this list should be used as a guide rather than definite recommendations.

Plant	*Common Name*	*Concentration*
Berberis Thunbergii	Dwarf Barberry	20 ppm.
Chrysanthemum	Chrysanthemum	5-10 ppm.
Deutzia lemoinii	Deutzia	20 ppm.
Dianthus	Carnation	10 ppm.
Diervilla florida	Weigelia	40 ppm.
Forsythia intermedia	Golden Bells	40 ppm.
Hydrangea paniculata	Four Seasons	20 ppm.
Juniperus spp.	Juniper	60-80 ppm.
Ligustrum amurense	Privet	40 ppm.
Lonicera tatarica	Bush honeysuckle	40 ppm.
Kolkwitzia	Beautybush	40 ppm.
Pelargonium	Geranium	5-10 ppm.
Potentilla fruticosa	Shrubby Cinquefoil	20-40 ppm.
Philadelphus spp.	Mockorange	20-40 ppm.
Rosa spp.	Garden Roses	10-20 ppm.
Spiraea spp.	Spiraea	40 ppm.
Syringa in variety	Lilac	80 ppm.
Taxus cuspidata	Japanese Yew	60-80 ppm.
Thuja occidentalis	Arborvitae	80 ppm.
Viburnum lantana	Wayfaring Tree	20 ppm.

All the treatments recommended above are for a period of 18 to 24 hours, using naphthylacetic or indolylbutyric acid.

The following table represents approximately corresponding strengths of commercial preparations in solution, based on results of tests and not on analysis.

Naphthylacetic	*Auxilin*	*Hormodin*	*Horotmone*	*Indanol*
80 ppm.	8 mg.	80 BTU	1-200	5 cc.-½ pt.
40 ppm.	4 mg.	40 BTU	1-400	" 1 pt.
20 ppm.	2 mg.	20 BTU	1-800	" 1 qt.
10 ppm.	1 mg.	10 BTU	1-1600	" ½ gal.

Commercial Products

For the person who will be using only small quantities of these materials, and who has no facilities for the accurate weighing of minute quantities of chemicals, the use of any of the commercial preparations mentioned here is recommended. These have all been tested at the Central Experimental Farm during the past summer in comparison with known strengths of indolylbutyric and naphthylacetic acids, and have proved effective.

The amount of active ingredients in each product varies, so that each must be used strictly in accordance with the directions sent out by its manufacturer. In most instances, in the experience of the authors, these directions have proved to be about the optimum treatment for the designated species and the necessity of following them accurately should be emphasized.

In listing the following products, one is not recommended above another, nor is it intended to discriminate against other products not mentioned here. These were the products obtainable on the Canadian market at the time the tests were started. They have been tried, and found satisfactory.

Solutions:

- Auxilin.
- Hormodin "A."
- Hortomone "A."
- Indanol.

Dust:

- Auxan.
- Rootone.

Dust Treatment

The above remarks have all dealt with the solution method of treating cuttings. It was the first practical method of applying hormone chemicals. More recently tests have been made by dipping the basal end of the cutting into dusts, such as talc, charcoal or diatomaceous earth, which contain a small portion of the active chemical in powdered form. The basal ½" or ¾" of the cutting is dipped into the dust as soon as the cutting is made. Any surplus dust is shaken or blown off and the cutting planted as soon as possible. Dust-treated cuttings receive the same cultural treatment as those treated with solutions.

The dust method of hormone treatment of cuttings has many advantages over the solution method. The dust is always ready to use without the delay of mixing fresh solutions. Actual treatment is exceedingly simple, and may be carried out very rapidly. Bundles of from 10 to 50 cuttings have been dusted at one time. Cuttings may be planted immediately, which saves labour in handling, as well as eliminating all the variable factors of light, temperature and humidity during treatment, as discussed earlier.

There is almost no danger of hormone overdosage when cuttings are dusted, as the actual chemical is made available to the cutting only gradually. In consequence, one concentration of hormone in dust covers a wide range of hormone requirements for rooting of cuttings. In recent tests at the National Research Council laboratories, with dormant cuttings of *Lonicera tatarica* (Tartarian honeysuckle), the untreated cuttings dusted with talc only rooted from 25 to 30 per cent. Treatment with 500 parts of indolylbutyric acid per million parts of talc effected 77 per cent rooting. Increasing the hormone concentration

to 1,000 and 2,000 ppm. only raised the rooting to 88 per cent. Dusts containing 750 to 1,000 ppm. of hormone chemicals are proving satisfactory. Higher concentrations are not required, and may cause a measure of damage.

While the dust method is a more recent development than the solution method of treatment, it is giving excellent results. In every species tested at the National Research Council laboratories, eventual rooting of dusted cuttings has been just as good as that of solution treated cuttings. In some instances, the response has not been quite so rapid. However, some plants give superior and more rapid rooting following dust treatment. The ease and safety of treatment make the dust method of treating plant cuttings particularly attractive and advantageous.

Preparation of hormone dust is not practical for the average horticulturist, and the use of commercially available dusts is recommended.

Summary of Cuttings

To summarize the work on cuttings, it has been found that the use of these chemicals has a stimulating effect on root production from cuttings of species and varieties which can normally be rooted with ease or moderate difficulty.

Their use in the commercial propagation of such plants as apple, plum, spruce, etc., which normally are extremely difficult to root from cuttings, cannot be recommended as yet. These chemicals are a stimulant to rooting rather than a cure-all for problems of plant propagation.

Treatment of Seeds

Interesting results have been obtained by treating seeds with dusts containing hormone chemicals. In many cases improved and more rapid germination occurs, and early growth is stimulated. The main effect seems due to the rapid development of a large root system. It is of interest to point out that these responses cannot be obtained to the same extent by soaking the seed. When seed is dusted with chemical, the active material is taken up slowly and there is not the same danger of shock as occurs when seed is soaked. While the stimulation which occurs from seed treatment is frequently striking, much experimental work is required before the hormone treatment of seed can be recommended for general practice. The hormone requirements of different seeds vary widely. It has been found that different varieties of the same crop also vary in their response to hormones. In consequence, recommendations regarding the treatment with hormones must be deferred until sufficient experimental evidence has been accumulated.

Grafting

Claims have been made that when these chemicals were applied to the union when grafting was in progress, or when the base of the scion was previously stood in solution, quicker union was effected and that the scion put out roots from its base.

Experience in one test made with lilacs in the winter of 1938 was that painting the wood had little effect. Where the scions were stood in solution, there was some stimulation of callus formation, but no increase in the percentage of successful grafts over the untreated ones.

Healing of Wounds

During the fall of 1937, and in the spring of 1938, bark wounds were made on young Green Ash trees (*Fraxinus pennsylvanica lanceolata*). In each case, the cambium layer was painted with linseed oil paint into which powdered indolylbutyric acid had been incorporated at rates of from 500 to 3,000 ppm. Some immediate stimulation of callus formation was observed in the spring series over untreated trees, but no improvement could be noticed by the end of the season.

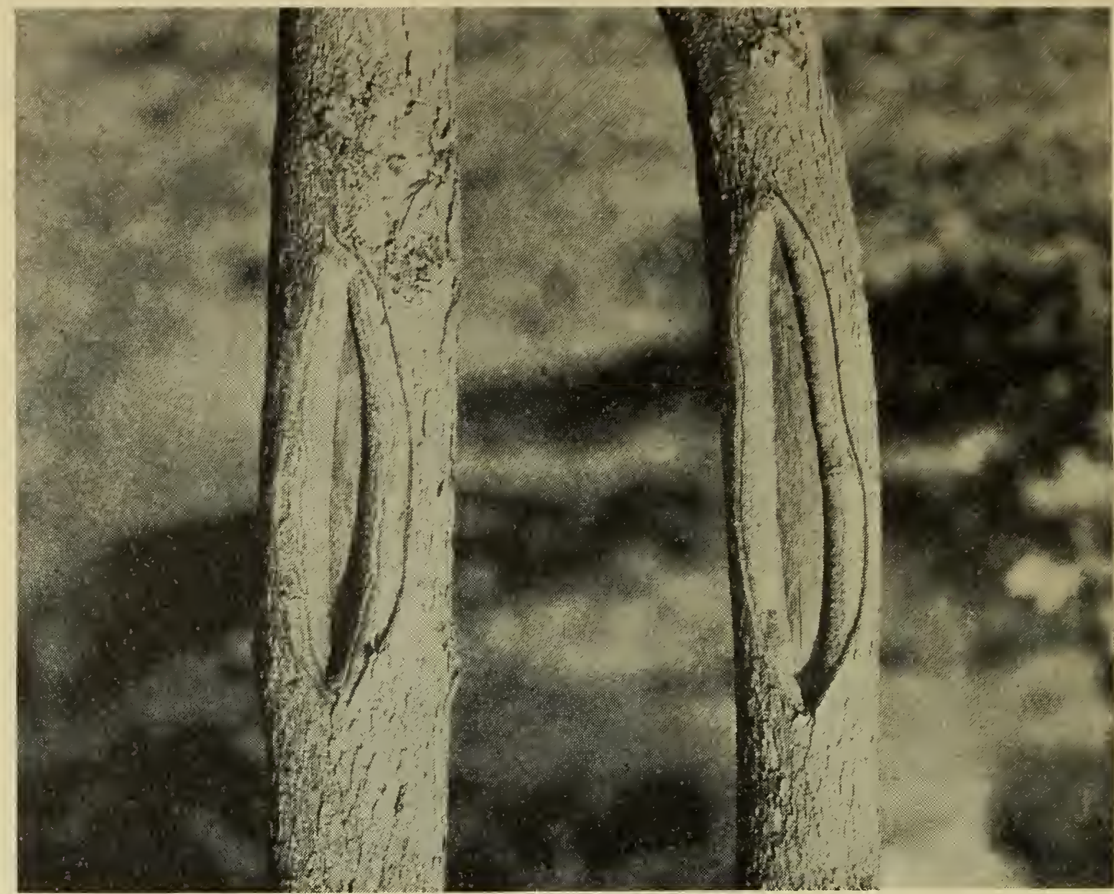

FIG. IV.—Treatment of wounds with hormones. Left 500 ppm. dust in linseed, right control.

Parthenocarpic Development of Fruits

During the winter of 1938, some imperfect varieties of strawberries, incapable of self-pollination, were grown in pots in a greenhouse. These had their blossoms sprayed with various concentrations of colchicine, indolylbutyric and naphthylacetic acids. This work was done by Dr. A. W. S. Hunter, Assistant in Fruit Breeding, Division of Horticulture, Central Experimental Farm.

In each case a good set of fruit was obtained, with normal-appearing plump seeds. Germination of these seeds was very low, although a few plants have resulted, and it is hoped that this method of producing homozygous plants may prove valuable in plant breeding work.

OTTAWA: Printed by J. O. PATENAUDE, I.S.O., Printer to the King's Most Excellent Majesty, 1940.